Discussion of "Pretreatments to Enhance Enzymatic and Microbiological Attack of Cellulosic Materials"

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Recent interests at Natick Laboratories have been towards pretreatment of a variety of cellulosic wastes, specifically to increase their susceptibility to enzymatic saccharification.

Dr. Millett (p.193) has enlightened us on the various chemical and physical pretreatments which increase the digestibility of cellulose. At Natick similar tests have been conducted, primarily in the area of physical treatment, using instead of wastes, newspaper as a standard substrate.

We have found that pretreatment is indeed necessary for us to have reasonable kinetics during the enzymatic hydrolysis. As far as the Natick process is concerned, the extent and type of pretreatment have yet to be established.

Table I shows a brief summary of a wide range of treatments and their effect on the percent saccharification in 4 and 24 hr. They are arranged in order of increasing susceptibility. Whereas Dr. Millett concentrated heavily on the chemical pretreatments, we have leaned more towards physical methods.

Our reasons for physical treatment are twofold:

1) enhanced enzymatic susceptibility (increased surface area and decreased crystallinity)

Biotechnol. & Bioeng. Symp. No. 5, 221-224 (1975)

TABLE I

Summary of the Results on Newspaper Susceptibility Following Various Pretreatments

Pretreatment 5% Newspaper	% Saccharification 4 hr	24 hr
Granulator-Comminuter 0.12	15	20
Boiled - wet	9	21
Soaked 20^{o} - wet	13	24
H. M. Jay Bee	12	24
Jet Pulverized - Single	16	26
Colloid Mill - 0.001 - wet	17	27
2% NaOH - wet	14	28
Varikinetic - wet	16	30
Mulched Mighty Mac	24	31
Viscose - wet	30	44
Cuprammonium - wet	35	52
Sweco Mill	28	53
Pot Mill	50	65

2) increased bulk density (increased slurry concentration in the hydrolysis reactor)

It should be noted that particle size is not the only contributing factor when considering a physical or milling treatment. The action of the mill, the milling history (i.e., time, temperature profile), all contribute to the change in crystallinity or change in susceptibility. This is shown best in Figure 1. The samples tested were Solka Floc. Hydrolysis was carried out using the 400 mesh fraction of the two samples. The lower curve represents this fraction obtained from a previously hammer milled floc SW40. The upper curve is the same size fraction obtained after SW40 had been ball milled. The effect on the kinetics is obvious.

Dr. Millett alluded to the prohibitive cost of some of the chemical treatments and briefly mentioned some similar economic problems in milling. He is quite correct.

I realize my discussion is not on the economics but since pretreatment affects the overall costs, perhaps I am justified in elaborating on the cost of milling.

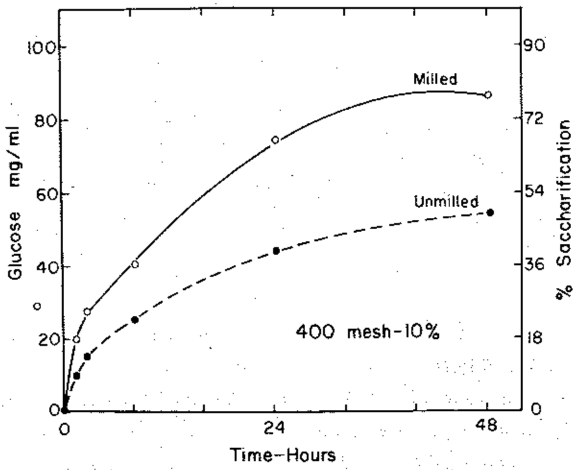

Fig. 1. Effect of milling on the susceptibility of Solka Floc SW40 fraction passing 400 mesh but not passing 500 mesh, ball milled fraction passing 400 mesh but not passing 500 mesh.

Presently, as far as I know, the processes both at Berkeley and Natick are based on the kinetic hydrolysis data using 50 micron average particle size cellulose substrate. This substrate is obtained by ball milling in one form or another. Just what does it cost to produce this substrate? Our findings are summarized in Table II. These estimates represent operating cost independent of the capital costs, so total cost may be higher than stated. In addition, I might also mention that we have experienced power costs as high as 18¢/lb using some of the more exotic physical treatments but in general the size reduction power costs are pretty much independent of the type of equipment used to accomplish the reduction.

In checking with large scale floc plants I have found the cost of producing 200 mesh floc is about 4 to 4.5¢/lb. This includes capital costs and therefore it seems to agree fairly well with Table II. The ball milling costs, assuming a 50% conversion of the substrate, translates into a glucose cost of between 8 and 9¢/lb for pretreatment. Other costs would obviously have to remain low for enzymatically produced glucose to be competitive.

Hence continued efforts to find a more reasonable substrate pretreatment should be pursured. Perhaps steam explosion or high energy irradiation with chemical treatment deserve closer looks or percent conversion versus degree of pretreatment could be played off to strike an optimum. This, however, may defeat our original objective of solid waste

TABLE II

Milling Costs

MESH SIZE	INCHES	MICRON	lbs/HpHr	POWER COST $/Ton	MAINTENANCE $/Ton	OVERHEAD COST $/Ton	TOTAL COST ¢/lbm
40	.0165	420	16	<$2.00	$1.40	$ .20	.18¢
80	.007	117	5	4.00	4.40	.40	.40
100	.0059	149	4	5.00	6.50	.50	.60
200	.0029	74	1	20.00	24.00	1.00	2.25
270	.0021	53	.55	36.45	45.00	1.40	4.14

disposal, especially if we grow the vast quantities of cellulose presently proposed. We will *create* a problem not solve one.

I realize this area of physical treatment is considered mundane by those of us who have our heads in the clouds over the enzymatic hydrolysis of waste cellulose. But the fact remains that it is not only an energy intensive process but also the single greatest cost factor in the economic evaluation of enzymatic processing of waste cellulose.